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AUTHOR Fellows, Nancy J.
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ABSTRACT

This paper documents the dynamics of the social interactions within two small groups of sixth grade students as they solved problems and attempted to understand the concepts related to the nature of matter and molecular theory. Similarities and differences of social interactions between the two groups are compared, and interpretations presented for how students might build on one another's ideas to construct their own personal meanings of the scientific concepts. Evidence from videotape transcripts of student interactions and student writing showed that students changed individual language explanations of phenomena. The teacher provided the support necessary to collectively reconstruct scientific explanations. There was no evidence that more knowledgeable peers were present in this sixth grade class, except for those who could remember the scientific language provided by the teacher and the text, which has the implications for how teachers structure experiences, problem solving and group interactions in science. Students constructed more useful and meaningful understanding as a result of sharing ideas in scientific language during problem solving activities. (Author)

Dynamics of Conceptual Change in Small Group Science Interactions

Nancy J. Fellows

Northeastern Illinois University

Paper presented at the American Educational Research Association
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ABSTRACT

This paper documents the dynamics of the social interactions within two small groups of sixth grade students as they solved problems and attempted to understand the concepts related to the nature of matter and molecular theory. Similarities and differences of social interactions between the two groups are compared, and interpretations presented for how students might build on one another's ideas to construct their own personal meanings of the scientific concepts. Evidence from videotape transcripts of student interactions and student writing showed that students changed individual language explanations after group discussions to form more elaborate and detailed explanations of phenomena. The teacher provided the support necessary to collectively reconstruct scientific explanations. There was no evidence that any more knowledgeable peers were present in this sixth grade class, except for those who could remember the scientific language provided by the teacher and the text, which has implications for how teachers structure experiences, problem solving and group interactions in science. Students constructed more useful and meaningful understanding as a result of sharing ideas in scientific language during problem solving activities.

Carol:	It says only to the rim. . . that's how far you're supposed to put it in. .
Kenny:	I know how to put it in, it says right here. . .
Doug:	You can see it coming out already!
Kenny:	It's working . . .
Doug:	I know. . . that's cool!
Kenny:	Look at it through the magnifying glass! . . . it's awesome!
Carol:	Oh, that's awesome. . .cool!

As these students watch sugar dissolve out of a tea bag into water they show an example of how students collaborate together to carry out a plan for experimentation. To carry out their plan they relied on prior experiences and on the new scientific information they were learning in science class. Prior to this experiment to try out their plan for getting sugar out of a tea bag, they agreed that sugar would dissolve in water. They had dissolved sugar into water at home. On their pretests they had answered that when sugar was put into water it disappeared or went to the bottom of the glass. Their understanding of "dissolving" at this point was still based on prior personal experience and had not yet been transformed into a useful, meaningful understanding of dissolving that could help them explain their world. As a result of instruction and group interaction in problem solving, these students began to conceptualize the process of dissolving in more scientific ways. What contributions might their group interactions have made to furthering each student's understanding of their science lessons?

The purpose of this study was to understand how eight students' conceptual learning changes were influenced by the conversation and social dynamics within their small group problem solving activities in sixth grade

science. The researcher set out to answer three questions about the how students' conceptual changes related to small group interactions:

(1) Did students' ideas change as a result of their interactions with other students? Did ideas discussed in the interpsychological plane show up in students' intrapsychological explanations?

(2) Were students able to use their new knowledge to make better, more useful scientific explanations of real world phenomena during and after group interactions?

(3) Was there evidence that interactions with a more knowledgeable peer helped students to broaden their understanding of scientific phenomena?

Learning and Conceptual Change in Science

The goal of teaching science concepts is to help students understand the world of science, and to make science concepts useful as students make sense of their worlds. Much of science seems difficult to usefully conceptualize for many students (Anderson & Roth, 1989; Anderson & Smith, 1983; Carey, 1986; Glaser, 1982; Posner, Strike, Hewson & Gertzog, 1982). Through research and observation we have found that when instruction encourages students to use their socially situated language and scientific tools to solve problems, students seem better able to use and understand science concepts (Brown & Campione, 1990; Fellows, in press; Linn, 1986; Palinscar, David, & Anderson, 1992; Lemke, 1990, among others).

Often learners come to science with real-world conceptions about phenomena that interfere with their ability to understand and use new science concepts. Students may not make the shift required in the kind of learning that requires them to accommodate their knowledge to fit new information. They especially have difficulty making the shift from real-world explanations of

phenomena to scientific explanations when they are unable to make the new science concepts useful (Carey, 1986; Driver & Easley, 1978; Anderson & Roth, 1989). Learning that requires students to change their concepts about phenomena appears to be a difficult kind of learning to accomplish, and often students do not make the switch. Students have been seen to take several alternatives to accepting scientific explanations: They will write scientific terminology and algorithms on their tests, but when provided a real-world event to explain, they revert to their common understandings, not necessarily scientifically based. Sometimes students will incorporate new science concepts within their already existing schema without changing their common explanations or theories about how the world works, sometimes retaining conflicting theories (Carey, 1986; Driver & Easley, 1978; Gunstone, Champagne & Klopfer, 1981; Roth, Smith & Anderson, 1983).

Relationship of Small Group Activities to Learning

Everyday vs. Scientific Conceptions. According to Vygotsky (1962) the beginning stage of concept acquisition is at the everyday or spontaneous level formed through children's daily experiences with their world in meaningful, first-hand encounters. Students acquire scientific concepts through social interaction with others, usually older or more experienced members of the culture. During classroom interactions between students and their teacher, or between students and a more knowledgeable peer, students' social interactions may play a major role in their developing understanding and their ability to self-regulate their inquiry in problem solving. As students engage in language interactions with one another about new concepts they are learning, experienced or knowledgeable peers might influence how the students formulate their explanations and descriptions, which would then transfer to understanding. Vygotsky claimed that individual thought processes (intrapsychological) originate in conversations with

others (interpsychological): New ways of thinking begin in conversation with another. As students in this study engaged in discussion about the concepts they were learning, new ideas should then form as a result of interactions with their peers.

Social construction of scientific knowledge. Knowledge exists not as disembodied events in an objective world, but is derived from socially mediated language interactions such as those found in conversation and books. The social process of making sense of experience in terms of scientific understandings produces knowledge that is a product of language interactions (Gergen, 1985; Harre, 1984; Mead, 1934; Vygotsky, 1962; Tobin, Espinet, Byrd, & Adams, 1988; Wittgenstein, 1953). Science learning is a constructive process requiring active involvement of the learner and the teacher (Inhelder & Piaget, 1958; Piaget, 1964.) Learners construct knowledge by recognizing their existing understanding and testing them with relationship to their experiences. Knowledge is socially constructed through experience in a social environment mediated by language (Gergen, 1985; Vygotsky, 1962). The social context of the learning experience and interactions with an adult communicate the values of the knowledge and forms of learning, which ultimately influences the form of the science knowledge understood by the student. In a socially constructed learning experience, language is used to confer and question ideas to make sense of the learning encounter.

An important part of the social construction of knowledge is the language interactions within oral and written discourse. Learning to know science in a socially mediated community comes from talking science (Bruner, 1966; Lemke, 1990; Vygotsky, 1962). When more knowledgeable members of the learning community, notably teachers, provide students with the language and coaching necessary to use scientific language to make assertions, explanations and

predictions, students talk through ideas as they make meaning and construct more coherent and organized scientific understandings (Edwards & Mercer, 1988; Halliday & Hasan, 1985; Lemke, 1990). When writing is added to talk it provides another means for students to communicate about their learning with other members of their community and reflect on what they know and what they still do not understand (Fellows, in press; Langer & Applebee, 1987; Rosaen, 1989; Roth, 1992).

Learning and the Human Brain

Meaningful learning requires multiple complex and concrete experiences, making connections through ongoing experiences. "The primary focus for educators, therefore, should be on expanding the quantity and quality of ways in which a learner is exposed to content and context" (Caine & Caine, 1991, p. 5). Talking about what they are doing and learning as they view, act and value enhances the meaningful learning that can take place for learners. The role of teaching is to encourage the learner to generate useful, more sophisticated and personally meaningful interconnections. Humans do not learn automatically from experience; how experience is used determines how much we learn. Teachers and adults can help students profit from their experiences by "orchestrating the immersion of the learner in complex, interactive experiences" in personally meaningful ways as they encourage the learner to actively process and analyze the experience (Caine & Caine, 1991, p. 104).

The brain is a social intellect. All regions of the brain interact and activities with the community and the environment become part of understanding (Gazzaniga, 1985). We receive and create meaning on our way to understanding. This understanding is often socially constructed (Vygotsky, 1978). The social brain has an innate drive to belong to a group and to relate to others. Students need to work in friendly groups where they feel relaxed, yet

alert, and supported. Learning increases when students interact by jointly solving problems; there seems to be a positive and critical link between verbal interaction and learning (Cohen, 1984; Cohen, Lohan, & Leechor, 1989). Talking in a group provides students with opportunities for processing experiences and reflecting on their understanding. Students rehearse their language explanations and reconstruct their knowledge as they engage in discussion with others. "Everyday use of relevant terms and the appropriate use of language should be incorporated in every course from the beginning" (Caine & Caine, 1991, p. 122).

The Curriculum Context

The instruction was planned by two principal researchers to teach the nature of matter and molecular theory and its application to real-world phenomena. Several research programs had developed, tested and refined the curriculum to assist students' conceptual changes (Anderson, Eichinger, Berkheimer & Blakeslee, 1990). The content covered matter, non-matter, pure substances and mixtures, and molecular behavior in changes of state, dissolving, and thermal expansion.

Students were taught prior to the matter and molecules unit to use successful collaborative social norms when interacting in their groups: They were encouraged to be sure that all members contributed to the group's efforts, all listened to the ideas of others, clarified and asked questions when they did not understand, and built on one another's ideas.

Students were taught during the last half of the unit to use scientific discourse terminology when explaining events. They were asked to first describe their assumptions or the facts they knew in the situation, then identify the substances involved, and explain and describe what happened to the substances and what happened to the molecules during the observed

phenomenon. The curriculum materials and the teacher reminded students to use this scientific discourse terminology on various levels. For instance, students were asked to explain what happened when sugar was stirred into water using scientific language and explanations. They shared their individual explanations and constructed new explanations in groups using the same scientific structure and terminology. Students observed models of scientific explanation like their own, and critiqued the explanations for content and structure. Students had many opportunities to follow the curriculum guides for composing scientific explanations about their observations.

Data Sources

The eight sixth-grade students in this study participated in a curriculum designed to engage them in small-group problem solving activities during which they used scientific concepts related to matter and molecules, practiced formulating explanations, and followed a specified set of social norms. Within the classroom, two groups of four students (total of eight) were targeted for intensive monitoring over a twelve week period. The students in the small group problem solving lessons were eight sixth-graders, six boys and two girls. Each group contained three boys and one girl. In group 1, two boys were African-American (Kenny, Antoine), one boy was Western European ancestry (Doug), and the girl was born in Laos, but raised in the United States (Carol). In group 2, one boy was of Western European ancestry (Norman), one boy was Iranian (Artie), and one boy was of Mexican heritage, born in Mexico, but raised in the United States (Jose). The girl in group 2 was of Western European ancestry (Melinda). All spoke English, but the Mexican heritage boy from Group 2 and the Laotian heritage girl in Group 1 spoke their native languages at home. Each group was mixed in achievement level based on previous performance.

At various points during the instruction, students wrote their ideas individually and in collaboration with small group members in a learning workbook or log. This workbook writing provided a snapshot of the ideas that students considered individually before and after group activity social interactions. Students participated in several small group problem solving activities where they were asked to predict, observe, describe and explain scientific phenomena. Videotapes of student interactions during small group activities served as data for interpreting the nature of students' social interactions and the ideas each presented. Each student was given a paper and pencil pretest prior to beginning the learning unit and the same test as a posttest at the end. Six of the students were clinically interviewed about the matter and molecules subject matter before and after instruction.

Methods

For this study I analyzed twelve weeks' videotaped lessons in matter and molecules in an attempt to specify the processes of group discussion occurring when students in small groups attempted to solve scientific problems and make descriptions and explanations of their observations. The lessons ran 40 to 50 minutes in length five days a week for twelve weeks. All spoken interactions in the group during lessons were transcribed as completely as possible from the videotapes. The transcript was supported by important nonverbal information from the videotape, student writing samples completed during the group activities, and observer's notes. Student writing, interviews, and videotaped activities were analyzed for the social norms present during interactions, the nature of concept explanations, who contributed ideas, what ideas were used, and what ideas remained over time.

To analyze the data I studied students' interactive behaviors using an anthropological approach of alternately viewing the videotapes and reading the

transcripts to arrive at descriptions of student behaviors. These descriptions were used to double-check the videotaped data and transcripts and further refine the comparisons. I looked at the overall organization of the group discussion in order to identify characteristic types of student-student interchanges and the scientific ideas established during the interactions. The purpose was to understand how the different interchanges between the students might facilitate or hinder the process of group discussion and children's understanding of scientific concepts. I was particularly interested in whether there was evidence that conversations during group activity showed up later in students' writing and whether the ideas persisted over time. I wanted to know if interactions with a peer mediated changes in thinking.

Results

Social Interactions Within Groups

Groups accomplished several activities to understand mixtures and matter and molecular behavior as a result of changes of state, dissolving, and thermal expansion. For instance during the dissolving lessons students had to make plans for getting sugar out of a tea bag, try the plans and make observations and explanations about what they observed when they tried their plan. Students also made plans for dissolving races, a slow race, fast race and a no-touch fast race. Students planned a group presentation and discussed group explanations for what they observed during the races.

Group 1. Group 1 consisted of Carol, Kenny, Antoine and Doug; occasionally Lucy would join the group when Antoine was absent. Throughout the early lessons, each student could be seen talking and contributing ideas to the group. Students followed the social group norms they had learned during previous instruction. About midway in the twelve weeks, Doug emerged as the student who had the "right" or "good" answers, and other students began to

follow his lead. Students continued to take turns talking and contributing ideas as new roles appeared. The students reacted to Doug as if he had the "right" answers, Carol began trying to get her ideas accepted as much as Doug's were accepted, saying she was smarter than he was because she had better grades. Students recognized that Doug usually "gets his way" (Kenny) because "mostly he's right" (Carol). Kenny was generally more quiet, listening to what Doug and Carol said, although he still attempted to interject his ideas at times when he had a contribution or an opening. Kenny challenged Carol and Doug's ideas if he did not agree. Kenny was one of the more shy students in the class which might explain his tendency to listen to Carol and Doug rather than contribute his ideas. Carol and Doug sometimes carried on conversations about the activities without including Kenny. At one point near the end of the twelve weeks Doug and Carol acknowledged something Kenny said and he got very excited: Kenny said, "Water hit against the sugar and broke the sugar down", and Doug said, "Yes", Carol nodded "Yes". Kenny excitedly said, "I was right!" Antoine was absent from several group activities due to illness, truancy and suspensions. Antoine's ideas were accepted and listened to in the early activities. Later in the lessons after he had been absent several times and did not know where the lesson had been or what the group was doing, he seemed to lose respect. The other group members sometimes helped him to catch up, but seemed to give up toward the end and let him do his work by himself or copy their writing. Doug and Carol took the lead in most discussions. Kenny, Doug, and Carol all contributed at different times to bringing the group back on task following a side discussion.

Group 2. Group 2 consisted of Melinda, Artie, Jose and Norman. During the early activities the group functioned according to three of the four social norms they had been taught: They each contributed ideas, listened and tried to clarify when they did not understand something. They seemed to have difficulty

building on one another's ideas in early sessions. They often resolved conflict by writing what each thought individually in their booklets. No leaders or other roles emerged until later in the unit when Artie began to move the group along by getting the others to vote on ideas and pushing them to accomplish tasks. Conflicts were also resolved by vote or majority and not by checking further to see what ideas were more consistent with scientific thinking. This group continued to talk and contribute equally during most of the twelve-week session. Artie pushed the group to accept his answers, or Norman's, and complete the tasks. Sometimes the others followed and sometimes they did not. Often Norman and Artie sided together against Melinda and Jose in debates. Even though Artie pushed the group, Melinda and Norman seemed interested in getting their answers right. Melinda would occasionally go from the group to check their ideas with the teacher. The most powerful group members seemed to be Artie and Norman because they would band together against the others. Often they would get their ideas accepted when they banded together. Jose continued to add his ideas to the discussions, although as the group progressed they used his ideas less. They did use ideas that were consistent with their thinking and worked out their differences on many occasions with discussion and reasoning. Not all decisions were made by force or status; many decisions were made by following previous instruction and the teacher's guidelines. Being able to remember something the teacher said helped give a group member the status to have their ideas accepted. The students took turns bringing the group back on task.

All of the group discussions were closely tied to the questions and activities in the science activity booklets. Activities were always structured to plan, write, talk, do, describe, explain, write, and talk again, in some order. The booklet directions for activities kept students on track directed them to the next

activities. The teacher would remind them as well. Students showed that they could use social norms to carry out sophisticated problem solving activities and resolve conflict. Group 2 got better at these interactions as time went on and they had more practice.

Ideas Obtained and Retained as a Result of Group Discussion

How much did interactions of peers show up in students' explanations and descriptions and stay with their thinking at the posttest? In general, each student seemed to refine current understanding and find better words for explanations during group discussions. For instance, Jose changed his written explanation of how sugar dissolves in cold water after the group discussion to include that cold water slows the process and the substance sugar and water mix together. He had not mentioned these particular explanations in his previous writing. Jose continued to use these explanations about sugar dissolving in water on his posttest and during the post clinical interview.

Each student demonstrated additions of new language to their explanations after group discussions that had not been present in their explanations before group discussion. After one discussion Carol added that molecules move farther apart to her explanation of dissolving. She kept that language to explain melting after instruction, but she did not keep that language for dissolving. For dissolving, she used the language that molecules move faster in hot water, but not that they move farther apart. Carol consistently used "moving faster" in her explanations of molecular behavior in dissolving and used "moving farther apart" in her explanations of melting. Melinda used the same language in her explanations even thought she was in a different group. Consistently students related molecules "moving farther apart" when substances got warm and melted or expanded. They described molecules "moving faster" when describing hot water and dissolving. This was not related to the teacher's

explanations, which mirrored scientific explanation, molecules increase both speed and distance when heated. It seemed that students' conceptual explanations and perhaps their understanding was tied to their visual and real world experiences with dissolving, melting and expanding--when a substance melts or expands it appears to move farther apart; when liquid is hot it appears to move faster.

Students made additions to their explanations, most in relationship to molecular movement in warmth and coldness and molecular action against other molecules. Other themes that emerged in group interactions that stayed with students' explanations were those describing molecular arrangement in various states, such as "rigid pattern" arrangements in the solid state. I was able to document at least four instances of additional explanatory language used by each student as a result of group interactions. An example of students' conversations showing how they built on one another's language to construct better explanations occurred when Group 2 was writing an overhead transparency to present to the class:

Melinda:	So, we put the sugar cube in frozen water. . .What is our plan?
Artie:	[writing on overhead] OK, now what is it?. . Put the sugar cube in frozen water, right?
Jose:	Ice cold.
Artie:	Put. . .[writing].
Norman:	. . sugar cube. . Put sugar cube in freezing cold water. . .
Melinda:	You gotta put a little dash. . .
Artie:	Uh. . .facts and observations. . .
Norman:	We assume the temperature will slow down the process?
Melinda:	The temperature will <u>affect</u> the process.
Artie:	So, we assume that the temperature will affect the process. OK, . . .the process . . what's a fact?
Norman:	That the sugar cube was going into the cold water.
Artie:	We'll put an observation. . . that the sugar cube dissolved. .
Melinda:	Dissolved in water.
Artie:	The sugar cube can dissolve in water.

There were several instances of misunderstanding that resulted from group interaction that students added to their explanations and sometimes kept

for much of the lesson. One example was the explanation that sugar turned into a liquid when it dissolved in water. During dissolving activities Group 2 discussed what happened when they tried their plan to dissolve sugar slowly. They began to write an explanation for what they saw and an argument began: Melinda and Jose said that the sugar dissolved and turned from a solid into a liquid. Artie and Norman argued that sugar did not turn into a liquid, but dissolved and broke down into tiny pieces. After several exchanges, Melinda went to ask the teacher about the correct answer. Before she could ask, the teacher told the students to begin their next activity, and began reviewing guidelines, so Melinda had to go back and sit down with her group. Her dilemma did not get resolved. Later the same day, when the teacher asked each group to recite what they wrote in their explanations, Carol from Group 1 read that their group wrote "the sugar turns into a liquid". The teacher let that pass, and moved on to the next student. Melinda raised both of her arms in a victory sign and looked at Artie and Norman as if to say, "See, I told you so!"

Melinda, Carol and Jose used this explanation after group interactions, even though some of their group members did not agree with them. They did not use these explanations toward the end of the lessons, however. These explanations either weren't any longer salient for them, or they had replaced them with others that seemed more useful, because these concepts did not appear in their explanations at the posttest or the post clinical interview.

In the case of each of the eight students, ideas of their peers seemed to help students broaden their understanding of scientific phenomena. The ideas they used from discussion were those related to molecular movement. The teacher had provided the language necessary to explain melting, dissolving and expanding phenomena. Each student was able to remember and use some of the language provided by the teacher in their initial individual written plans,

observations and explanations, and helped the group to collectively reconstruct scientific language explanations to describe and explain their observations. After discussing their written explanations in groups, students showed additions of more detail in their individual written explanations. Often this detail stayed in their explanations, especially, it seemed, if the explanation matched their experiences, i.e. molecules move faster in hot water and move farther apart when metal is heated. If more elaborate explanation is evidence that a student has broadened her understanding of scientific phenomena, then these eight students benefitted from group discussion of the scientific ideas. Before Kenny came to the group to discuss explanations for plans to get sugar out of a tea bag by placing it in water he wrote: "when sugar gets in water for a long time it will evaporate. The sugar will dissolve. The sugar molecules will go in the water.". After the group discussion with Carol, Doug and Antoine about what the explanation should be for using water to get the sugar out of the tea bag, Kenny wrote "There are holes in the tea bag. Sugar will dissolve into a liquid. They move farther apart . . . The water breaks down the sugar so it can go through the tea bag. The sugar is dissolving and turning into sugar molecules." Kenny retained this explanation that water breaks down sugar and turns it into sugar molecules in several explanations after this instance and continued to use that language after instruction.

Discussion

The evidence from students' writing before and after group interactions showed that each of the eight students changed their explanations after interacting with the others about the scientific explanations of their observations. Students seemed to select which details they would add to their explanations, because they did not add all of the details from the discussions to their writing. It could be that due to limitations on the amount of information they could process

at one time and get down in writing, students efficiently kept those ideas that seemed most useful and salient to them. That might explain why molecular movement explanations seemed to mimic students' macroscopic observations.

The additions that students made to their individual explanations after group discussions seemed to enlarge and add more scientific language. It seemed to this observer that students continued to use the language that they found most useful to explain the phenomena. Some of this language originated from listening to the teacher and reading information. Some of the language remained because it was socially reconstructed in the group interactions. Once language was socially reconstructed in group interaction and used by a student in his or her individual explanations, it tended to remain as part of the students' explanation. The language that students added to their explanations was still limited and not always complete to fully explain the observed phenomena in scientific language. It could be that students' experiences and prior knowledge limited their capacity to remember and use all of the details they needed for complete explanations.

The more knowledgeable peers in group interactions had influence over what students decided to use in their explanations. If a student was perceived to be "right" as was Doug in Group 1, or consistent with what the teacher had said, the students were likely to agree to using the language as part of their group explanations. As a result of constructing the group explanations, most students at some time used the language of the group as part of their individual explanations, showing that ideas discussed by more experienced peers can help students broaden their own language possibilities. In a subject such as the nature of molecules and physical change, there are not many very knowledgeable peers in the sixth grade, so an important aspect of students' knowledge construction was the scientific language and explanation discourse

provided by the teacher and the curriculum. In the areas where the teacher had not provided language for students to "play with", or students had not remembered the language she provided, there were no "more knowledgeable" peers to help in the social construction of students' scientific knowledge. Students probably remembered more scientific language and used it as a result of the collective reconstruction that occurred in the group discussions than they would have remembered and used in the absence of group language interactions.

Educational Significance

This study contributes to the body of conceptual change literature and supports Vygotskian, social constructivist theories and brain research by confirming those studies that propose students learn science best when they have opportunities for socially situated problem solving, using their language and the tools of science to apply, predict, describe, and explain new science concepts.

This study provided deeper understanding about how sixth grade students carry out sophisticated social interactions around problem solving activities and help each other construct more elaborate and accurate explanations. Such interactions seem to support more than hinder students' understanding of scientific concepts. Inaccuracies resulted from the discussions at times. With further discussion, teacher explanations and practice with the language, students seemed to resolve many of their inaccuracies.

Because students in sixth grade science are usually all novices in understanding the nature of matter and physical change, it will be difficult for them to help one another construct deeper understanding in conversation with one another. It will be important in many science situations such as this, where students have little prior scientific understanding about the subject matter, for

teachers to provide the scientific language students need. Students need to talk about the subject in complex and appropriate ways to feel comfortable about the subject and master it (Caine & Caine, 1991); students need to use relevant terms and appropriate language of science in everyday conversation throughout their lessons. Teachers will need to provide the scientific language, and they will need to carefully structure the learning environment to provide students with opportunities to use appropriate scientific language in real scientific experiences in a social context. These teaching practices may require changes in current curricula and classroom climates. The language of science needs to be mastered. Students need to use the language of science to obtain feedback about the environment and their understanding of it. Language also mediates between students' brain systems and their conscious and unconscious mind. "Language reports the cognitive computations of other mental modules" (Gazzaniga, as reported in Caine & Caine, 1991).

> We simply must part with the idea that specific pieces of information "taught" to learners for rewards is an effective use of our brains or theirs. That type of teaching does not work well and does not engage the brain sufficiently. For the shift to occur, we need to seek the patterns that connect. The answer lies in teaching for meaning. (Caine & Caine, 1991, p. 180).

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